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(54) **OPTICAL SENSOR HAVING A CHARACTERISTIC CHANGING PART IN A CHARACTERISTIC LIGHT GUIDING MEMBER**

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G01B 11/16 (2006.01)

G01D 5/26 (2006.01)

(52) **U.S. Cl.**

CPC **G01D 5/353** (2013.01); **G01B 11/16** (2013.01); **G01D 5/268** (2013.01); **G01D 5/35306** (2013.01); **G01D 5/35367** (2013.01)

(58) **Field of Classification Search**

CPC . G01D 5/268; G01D 5/353316; G01D 5/353; G01B 11/16; G01B 11/18; G01B 11/24

USPC 250/227.14-227.19; 385/8-13
See application file for complete search history.

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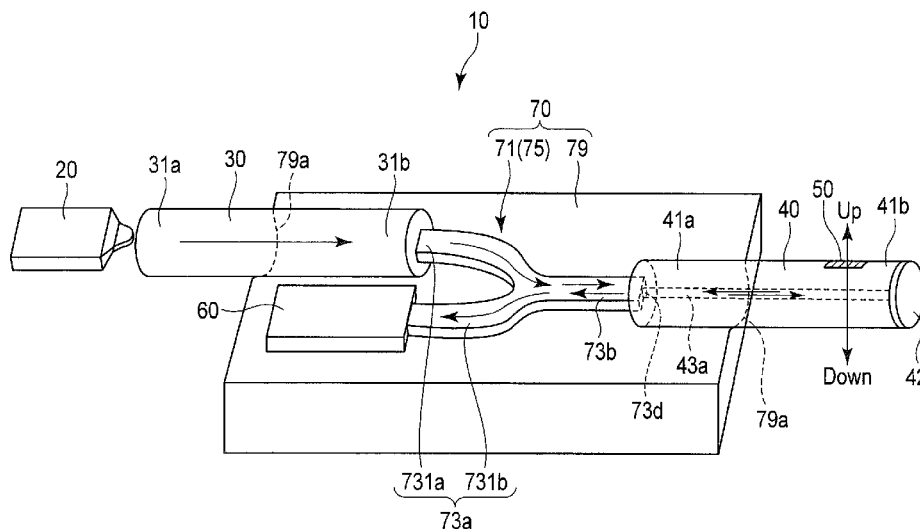
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(57) **ABSTRACT**

An optical sensor has a light source, a characteristic light-guiding member, a characteristic changing part, a detecting unit, and an optical connecting unit. The optical connecting unit has a light branching unit configured to branch the light emitted from the light source to the characteristic light-guiding member, and branches the light guided by the characteristic light-guiding member to the detecting unit.

8 Claims, 11 Drawing Sheets



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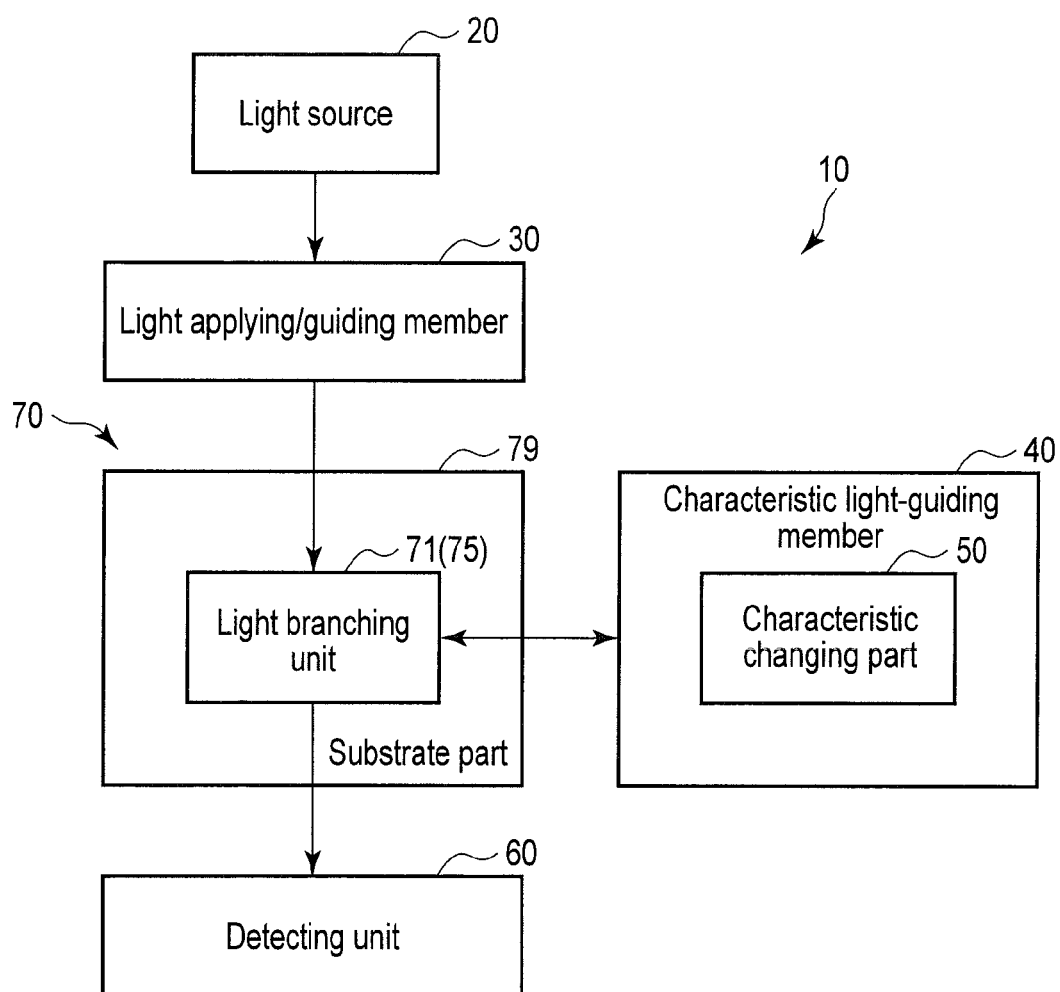


FIG. 1A

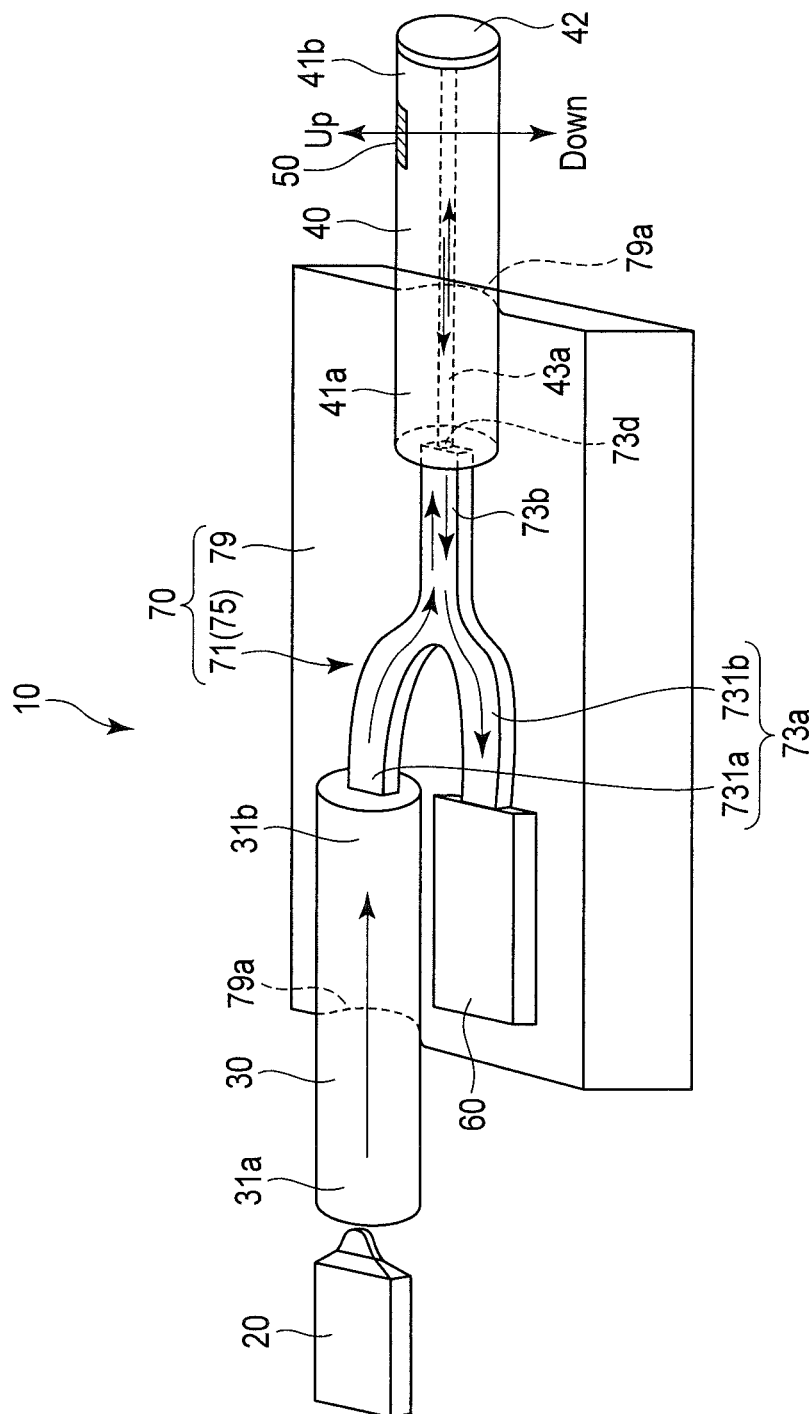


FIG. 1B

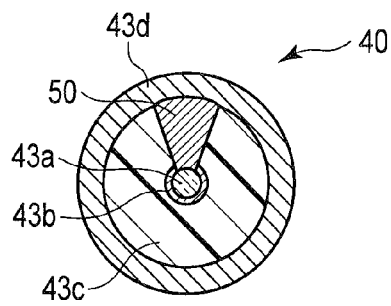


FIG. 1C

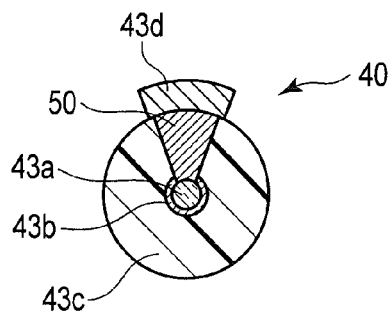


FIG. 1D

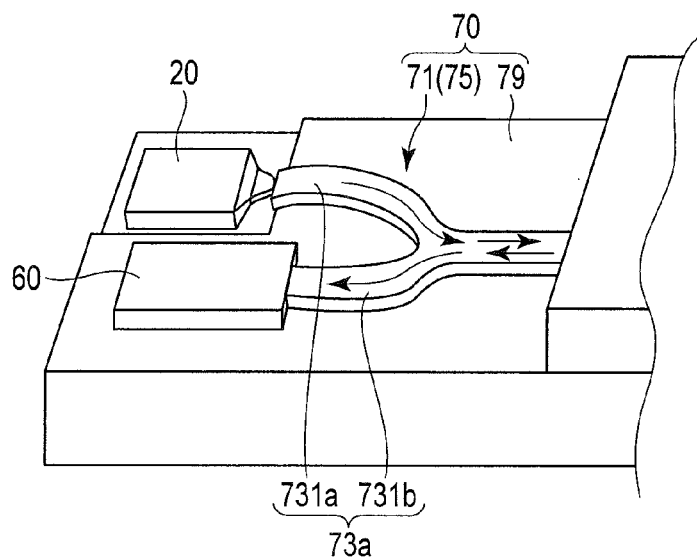


FIG. 1E

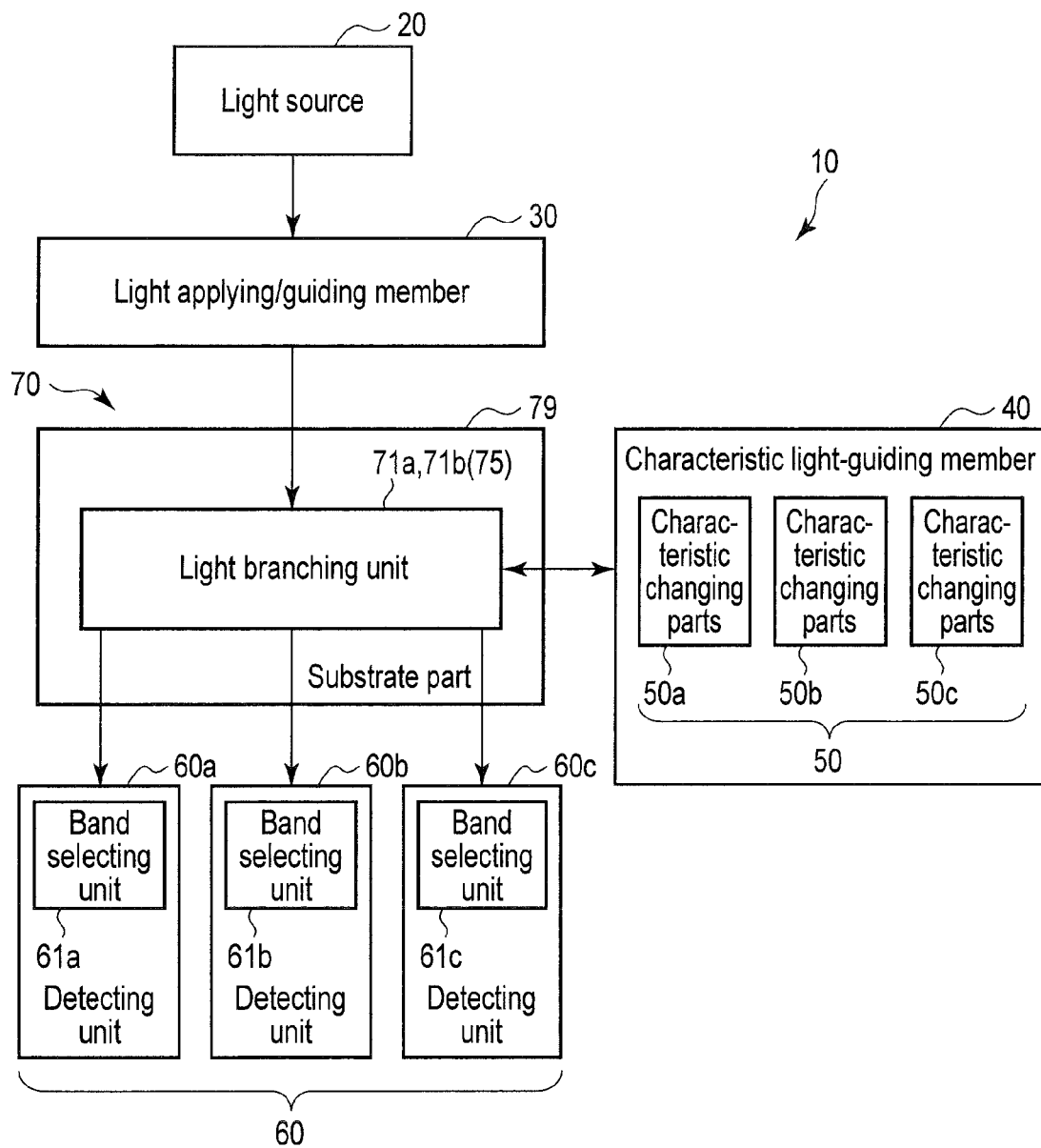


FIG. 2A

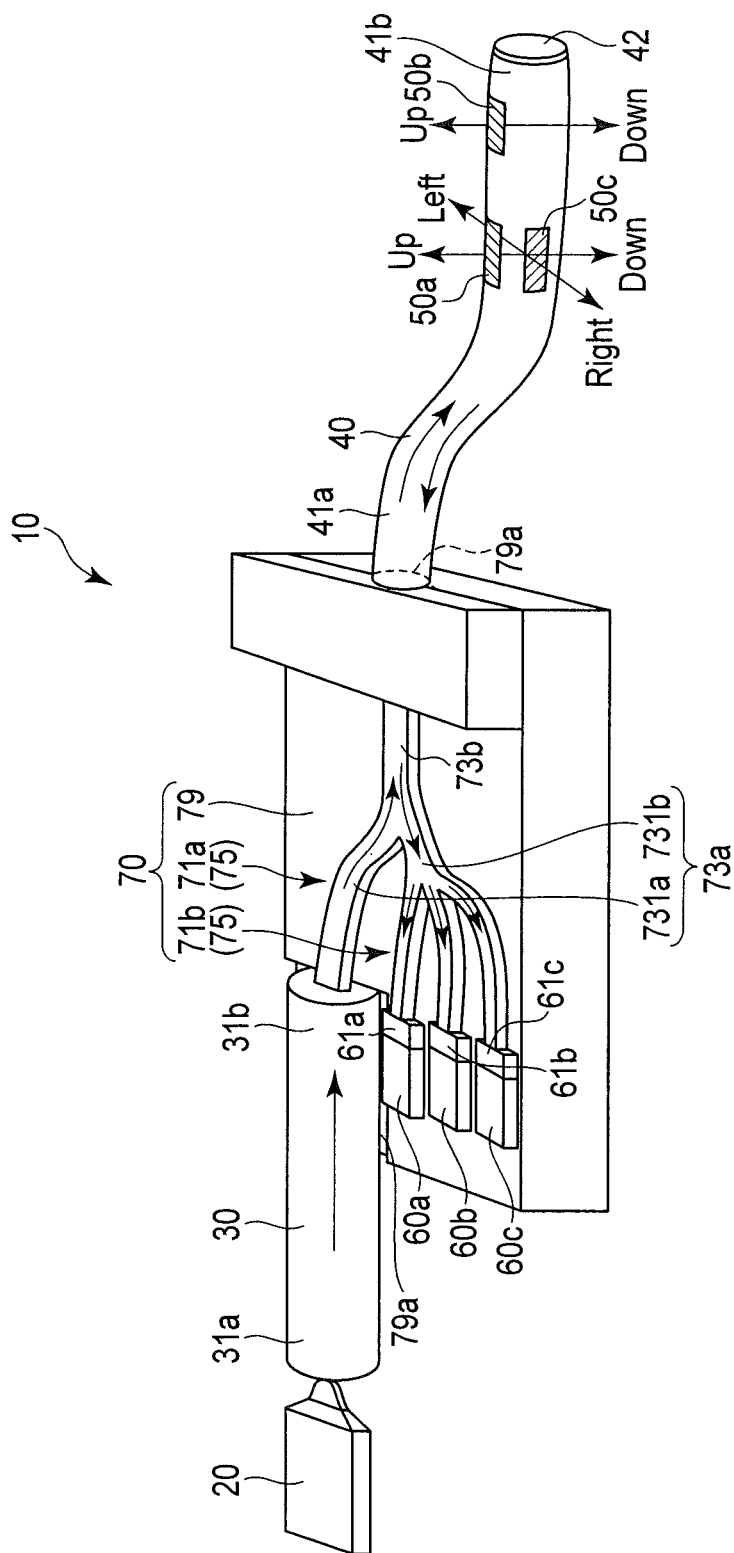


FIG. 2B

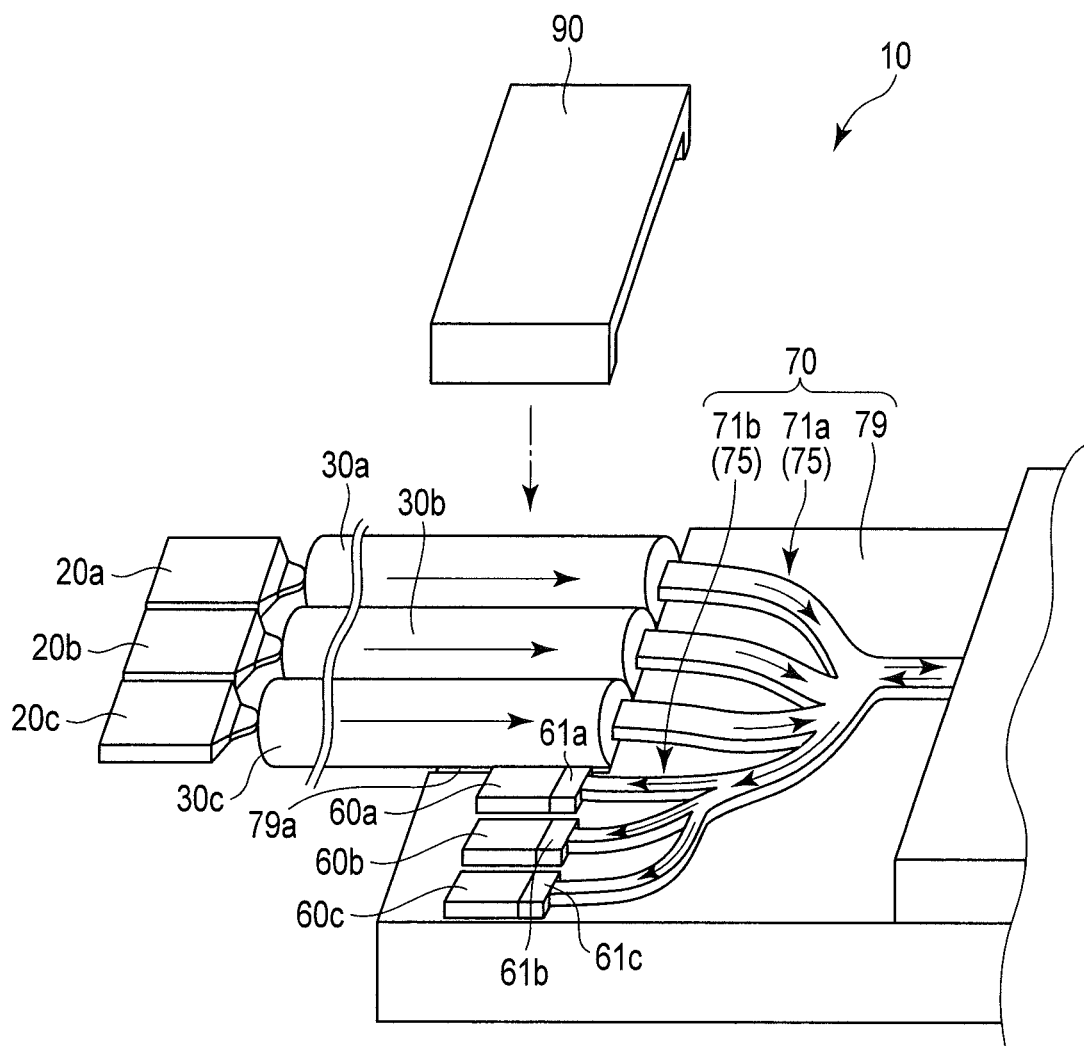
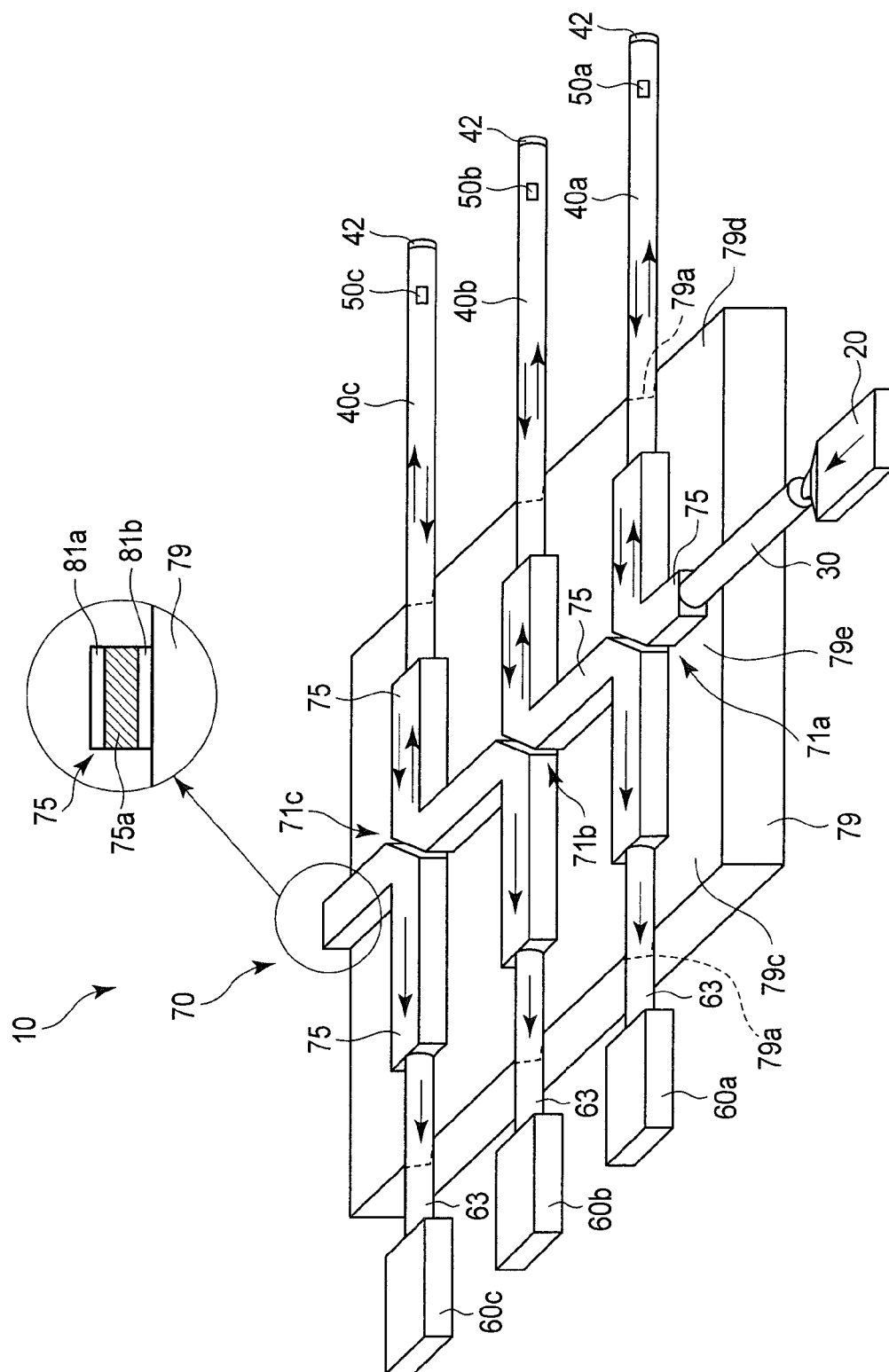


FIG. 2C



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G.
F

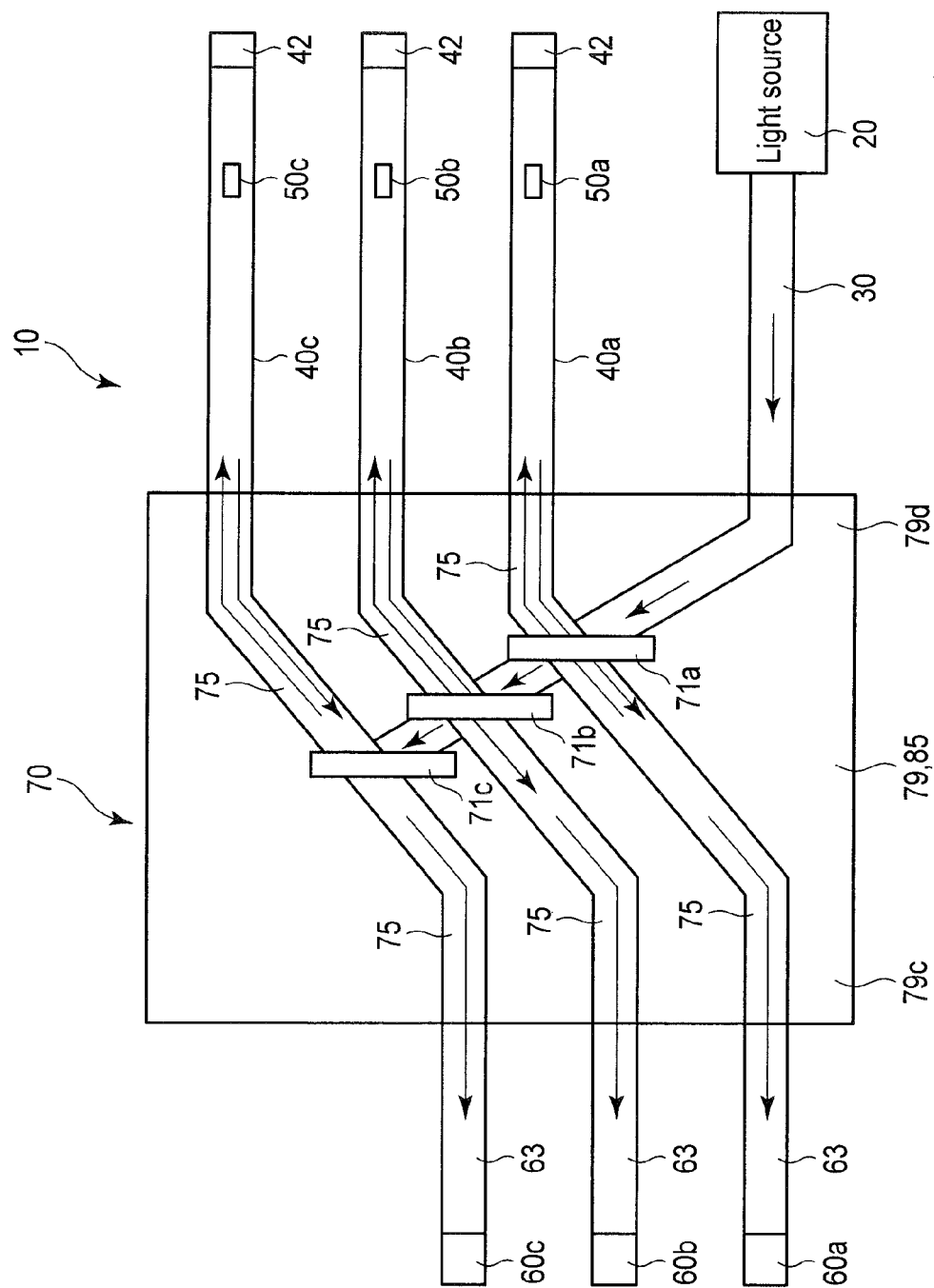


FIG. 4A

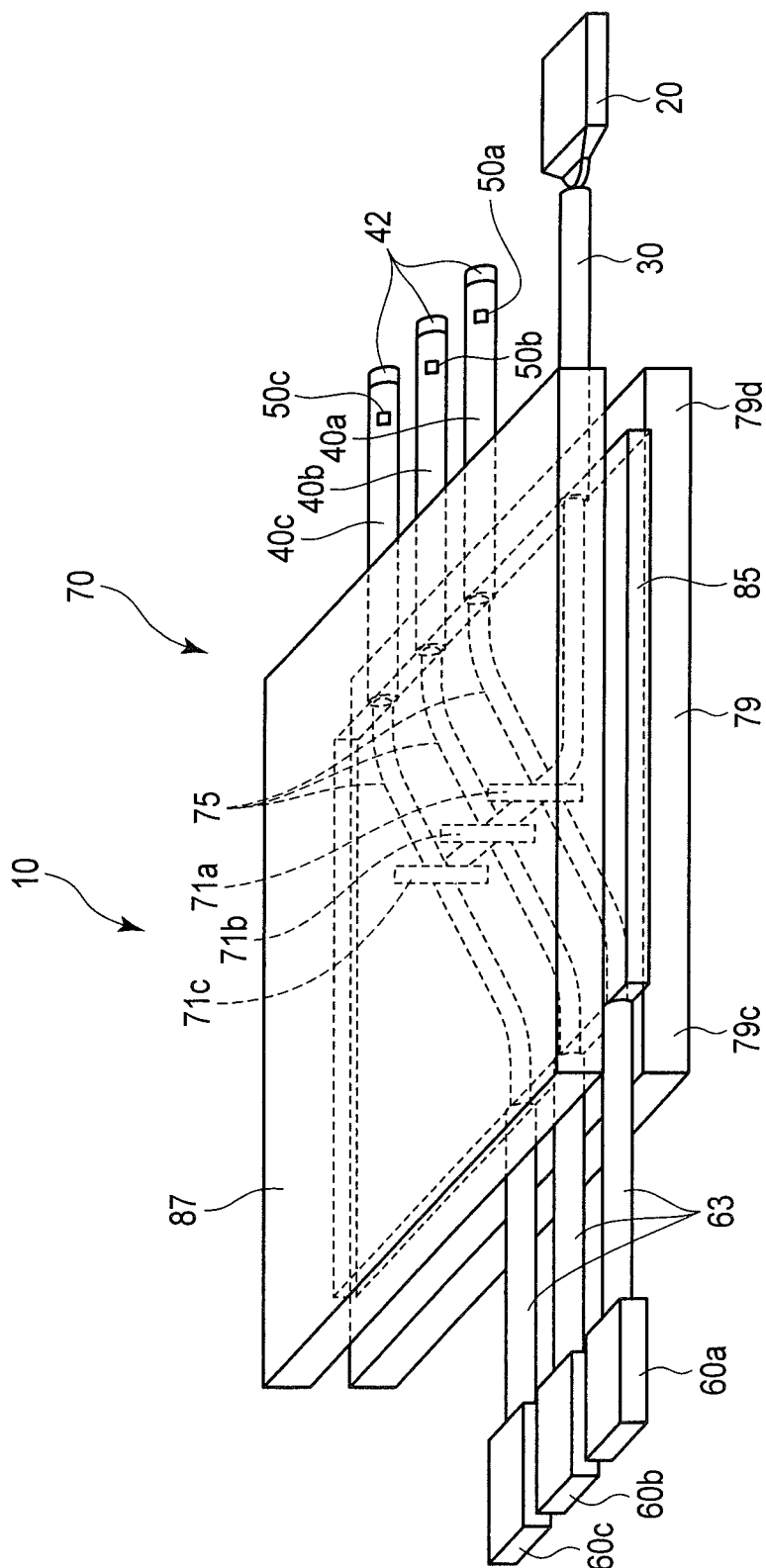


FIG. 4B

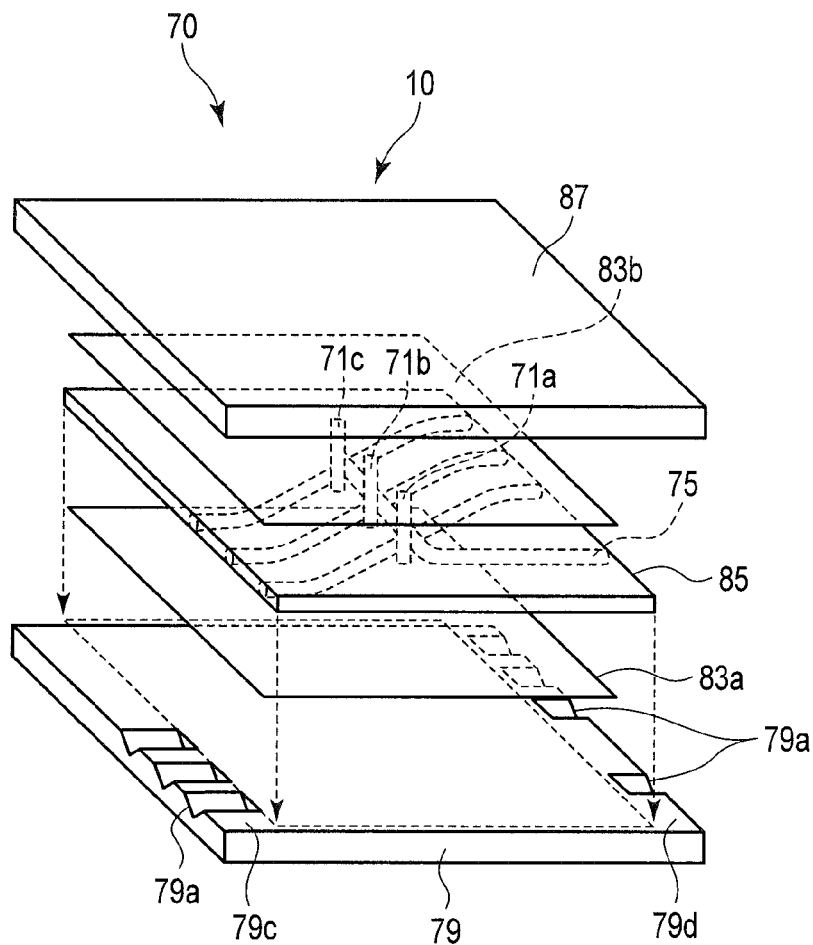


FIG. 4C

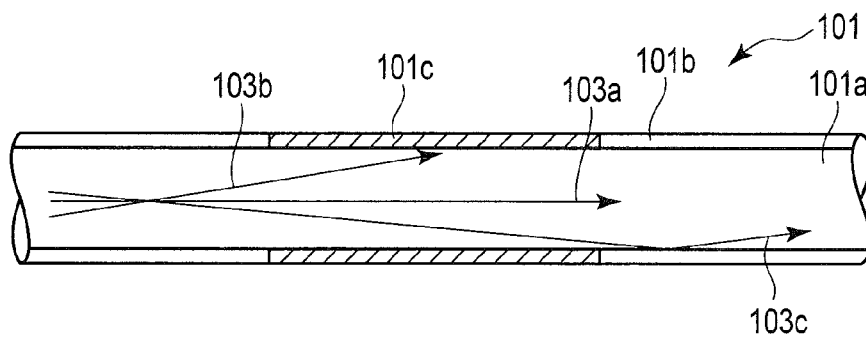


FIG. 5A
Prior Art

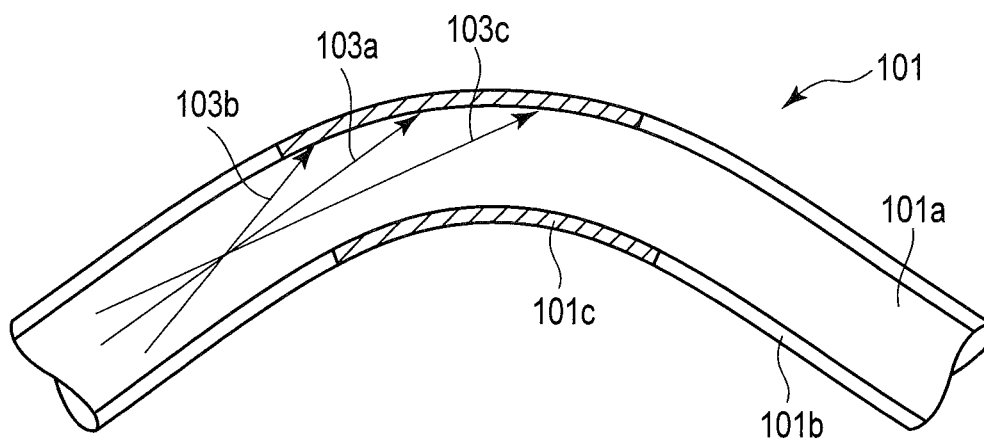


FIG. 5B
Prior Art

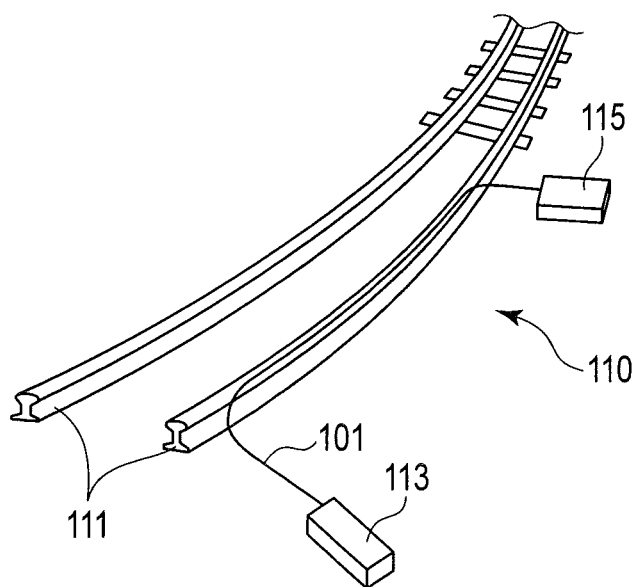


FIG. 5C
Prior Art

OPTICAL SENSOR HAVING A CHARACTERISTIC CHANGING PART IN A CHARACTERISTIC LIGHT GUIDING MEMBER

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Continuation application of PCT Application No. PCT/JP2013/050832, filed Jan. 17, 2013 and based upon and claiming the benefit of priority from prior Japanese Patent Application No. 2012-017178, filed Jan. 30, 2012, the entire contents of all of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an optical sensor.

2. Description of the Related Art

For example, Jpn. Pat. Apply. KOKAI Publication 57-141604 discloses an optical fiber. As shown in FIG. 5A, the optical fiber **101** has a core **101a**, a cladding **101b** covering the core **101a**, and a light absorbing part **101c** which is provided in the cladding **101b**.

How light propagates in the optical fiber **101** will be explained.

As shown in FIG. 5A, in the case, the optical fiber **101** extends straight, light **103a** propagating in the axial direction of the optical fiber **101** is guided at all. Light **103b** propagating at a first angle to the axial direction is absorbed by the light absorbing part **101c**. Light **103c** propagating at a second angle to the axial direction is not absorbed by the light absorbing part **101c**, is totally reflected by the cladding **101b** and is guided forwards.

As shown in FIG. 5B, the optical fiber **101** may be bent at the light absorbing part **101c**. In this case, lights **103**, **103b** and **103c** propagate toward the light absorbing part **101c**. As a result, the lights **103**, **103b** and **103c** are absorbed by the light absorbing part **101c**, and will no longer propagate.

The amount of light guided is thus controlled.

The optical fiber **101** so configured may be used in such a curvature measuring device **110** as shown in FIG. 5C. The device is a representative optical sensor which measures amount of displacement of the optical fiber **101**. The curvature measuring device **110** shown in FIG. 5C has an optical fiber **101** shown in FIG. 5A and laid along a rail **111**, a laser light source **113** connected to one end part of the optical fiber **101**, and a photoelectric transducer device **115** connected to the other end part of the optical fiber **101**. The optical fiber **101** is bent in compliance with the curvature of the rail **111**. In proportion to the curvature of the rail **111**, the light decreases in amount as it propagates in the optical fiber **101** from the laser light source **113** to the photoelectric transducer device **115**. The photoelectric transducer device **115** measures the decrease in the amount of light. From the decrease in the amount of light, the curvature of the rail **111** and the downward flexure of the rail **111** will be determined when a train passes through.

As shown in FIG. 5C, for the optical sensor is arranged in the outdoor, the optical sensor cannot easily be incorporated in small high-precision devices in view of the arrangement of the optical fiber **101**. In the optical sensor shown in FIG. 5C, the laser light source **113** is arranged at one end part of the optical fiber **101**, and the photoelectric transducer device **115** is arranged at the other end part of the optical fiber **101**. The optical sensor shown in FIG. 5C is inevitably large.

In view of the above, this invention has been made to provide a small optical sensor that can be incorporated in small high-precision devices.

BRIEF SUMMARY OF THE INVENTION

An aspect of an optical sensor of the present invention includes a light source configured to emit light; a characteristic light-guiding member configured to guide the light emitted from the light source; a characteristic changing part arranged in the characteristic light-guiding member and configured to change an optical characteristic of the light in accordance with how much the characteristic light-guiding member is bent; a detecting unit configured to detect the light changed in optical characteristic by the characteristic changing part and guided by the characteristic light-guiding member; and an optical connecting unit configured to connect optically the light source, the characteristic light-guiding member and the detecting unit, wherein the optical connecting unit has a light branching unit configured to branch the light emitted from the light source to the characteristic light-guiding member, and to branch the light guided by the characteristic light-guiding member to the detecting unit.

Advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. Advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention, and together with the general description given above and the detailed description of the embodiments given below, serve to explain the principles of the invention.

FIG. 1A is a schematic diagram showing an optical sensor according to a first embodiment of this invention;

FIG. 1B is a schematic perspective view of the optical sensor shown in FIG. 1A;

FIG. 1C is a sectional view of a characteristic light-guiding member including a characteristic changing part;

FIG. 1D is a sectional view of the characteristic light-guiding member including a characteristic changing part;

FIG. 1E is a schematic perspective view of the optical sensor, showing that the light source shown in FIG. 1B is directly and optically connected to the optical connecting part;

FIG. 2A is a schematic diagram showing an optical sensor according to a second embodiment of this invention;

FIG. 2B is a schematic perspective view of the optical sensor according to the second embodiment;

FIG. 2C is a schematic perspective view of an optical sensor in which a plurality of light sources and a plurality of light-guiding members are arranged;

FIG. 3 is a schematic diagram showing an optical sensor according to a third embodiment of this invention;

FIG. 4A is a schematic diagram showing an optical sensor according to a fourth embodiment of this invention;

FIG. 4B is a schematic perspective view of the optical sensor shown in FIG. 4A;

FIG. 4C is an exploded perspective view of the optical sensor shown in FIG. 4B;

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FIG. 5A is a diagram showing an optical fiber of the general type, which extends straight;

FIG. 5B is a diagram showing the optical fiber shown in FIG. 5A, which is bent; and

FIG. 5C is a diagram showing a curvature measuring device which is a representative optical sensor having the optical fiber shown in FIG. 5A.

DETAILED DESCRIPTION OF THE INVENTION

Embodiments of this invention will be described in detail, with reference to the accompanying drawings.

First Embodiment

[Configuration]

The first embodiment of this invention will be described, with reference to FIG. 1A, FIG. 1B, FIG. 1C and FIG. 1D.

As FIG. 1A and FIG. 1B show, the optical sensor 10 has a light source 20 for emitting light, a light supplying/guiding member 30 for guiding the light emitted from the light source 20 to supply the light, and a characteristic light-guiding member 40 for further guiding the light guided by the light supplying/guiding member 30. The optical sensor 10 further has a characteristic changing part 50, a detecting unit 60, and an optical connecting unit 70. The characteristic changing part 50 is arranged in the characteristic light-guiding member 40 and configured to change the optical characteristic of the light guided by the light-guiding member 40, in accordance with how much the characteristic light-guiding member 40 is bent. The detecting unit 60 detects the light changed in optical characteristic by the characteristic changing part 50 and guided by the characteristic light-guiding member 40. The optical connecting unit 70 optically connects the light supplying/guiding member 30, the characteristic light-guiding member 40 and the detecting unit 60.

As shown in FIG. 1B, the light source 20 is optically connected to the light supplying/guiding member 30. The light emitted from the light source 20 is applied to the light supplying/guiding member 30. The light source 20 has, for example, a laser for emitting a laser beam or an LED light source for emitting an LED beam.

As shown in FIG. 1B, the light supplying/guiding member 30 has one end part 31a optically connected to the light source 20, and the other end part 31b optically connected to the optical connecting unit 70. The light supplying/guiding member 30 has, for example, flexibility. The light supplying/guiding member 30 has, for example, an optical fiber.

As shown also in FIG. 1B, the characteristic light-guiding member 40 has an end part 41a optically connected to the optical connecting unit 70, and the other end part 41b having a reflecting part 42. The reflecting part 42 reflects the light guided from the end part 41a, back to the end part 41a. The reflecting part 42 has, for example, a mirror.

The characteristic light-guiding member 40 has, for example, flexibility. The characteristic light-guiding member 40 has, for example, an optical fiber. As shown in FIG. 1C and FIG. 1D, the characteristic light-guiding member 40 has a core 43a, a cladding 43b covering the core 43a, and a jacket 43c for covering the cladding 43b and protecting the cladding 43b. The cladding 43b and the jacket 43c are cut in part, making a slit. In the slit, the characteristic changing part 50 is arranged. The characteristic changing part 50 is thus embedded in the characteristic light-guiding member 40. The inner circumferential surface of the characteristic changing part 50 contacts the core 43a. The outer circumferential surface of the characteristic changing part 50 does not protrude from the

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outer circumferential surface of the jacket 43c in a radial direction of the characteristic light-guiding member 40. Rather, it is flush with the outer circumferential surface of the jacket 43c. The sides of the characteristic changing part 50 contact the sides of the cladding 43b and the sides of the jacket 43c. The characteristic changing part 50 need not fill up the slit, and may have appropriate hardness and appropriate thickness. In this case, the characteristic changing part 50 has the thickness corresponding to the reaction of light of the characteristic changing part 50.

The characteristic changing part 50 may have, for example, a light absorbing part for absorbing light. In this case, the amount of light the characteristic changing part 50 absorbs depends on how much the characteristic light-guiding member 40 is bent. If the characteristic light-guiding member 40 is bent upwards, positioning the characteristic changing part 50 inside the characteristic light-guiding member 40 so bent, the characteristic changing part 50 will absorb less light than in the case where the characteristic light-guiding member 40 extends straight. If the characteristic light-guiding member 40 is bent downwards, positioning the characteristic changing part 50 outside the characteristic light-guiding member 40 so bent, the characteristic changing part 50 will absorb more light than in the case where the characteristic light-guiding member 40 extends straight. As the amount of light the characteristic changing part 50 absorbs increases or decreases, the amount of light propagates to the detecting unit 60 changes.

Thus, the characteristic changing part 50 changes the optical characteristic in accordance with, for example, how much the characteristic light-guiding member 40 is bent. As shown in FIG. 1B, the characteristic changing part 50 is arranged at a desirable point in the lengthwise direction of the characteristic light-guiding member 40, for example at the other end part 41b of the characteristic light-guiding member 40.

As shown in FIG. 1C, the characteristic light-guiding member 40 including the characteristic changing part 50 is covered with a protective member 43d and is protected by the protective member 43d. The protective member 43d may cover only the characteristic changing part 50, as shown in FIG. 1D. Thus, the protective member 43d only needs to cover and protect at least the characteristic changing part 50.

The characteristic light-guiding member 40 may be either integral with, or a member independent of, the light supplying/guiding member 30.

As shown in FIG. 1A and FIG. 1B, the optical connecting unit 70 has a light branching unit 71 and a substrate part 79. The light branching unit 71 branches the light emitted from the light source 20 to the characteristic light-guiding member 40, and branches the light guided by the characteristic light-guiding member 40 to the detecting unit 60. The substrate part 79 has a light guiding path 75 that includes the light branching unit 71.

As shown in FIG. 1B, the light branching unit 71 is branched into two end parts 73a, and other end part 73b. The end 731a of the end part 73a is optically connected to the other end part 31b of the light supplying/guiding member 30. The other end 73b is optically connected to one end part 41a of the characteristic light-guiding member 40. The other end 731b of the end part 73a is optically connected to the detecting unit 60. The light branching unit 71 can therefore guide the light by guided the light supplying/guiding member 30 to the characteristic light-guiding member 40, and guide the light by guided the characteristic light-guiding member 40 to the detecting unit 60. The light branching unit 71 prevents the light guided by the light supplying/guiding member 30 from propagating to the detecting unit 60, and prevents the light guided by the characteristic light-guiding member 40 from

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propagating back to the light supplying/guiding member 30. The light branching unit 71 therefore functions as light guiding path 75. The light branching unit 71 is composed of a film having a low refractive index and two films having a high refractive index and sandwiching the film having the low refractive index.

The light source 20 and the detecting unit 60 are arranged at the other end part 73a of the light branching unit 71. The characteristic light-guiding member 40 including the characteristic changing part 50 is arranged at the other end 73b of the light branching unit 71. The optical sensor 10 is arranged so that the light emitted from the light source 20 is reflected at the reflecting part 42 used as a relay point and then guided to the detecting unit 60.

The substrate part 79 has a recess part 79a. In the recess part 79a, the other end part 31b of the light supplying/guiding member 30 and the end part 41a of the characteristic light-guiding member 40 are held, whereby the light branching unit 71 is optically connected to the light supplying/guiding member 30, characteristic light-guiding member 40 and detecting unit 60. The recess part 79a is, for example, a V groove or a U groove. Since the other end part 31b of the light supplying/guiding member 30 and the end part 41a of the characteristic light-guiding member 40 are held in the recess part 79a, the core (not shown) of the light supplying/guiding member 30 is optically connected to the core 73d of the light branching unit 71. As a result, the core 43a of the characteristic light-guiding member 40 is optically connected to the core 73d of the light branching unit 71. At this point, the other end part 31b of the light supplying/guiding member 30 and the end part 41a of the characteristic light-guiding member 40 are mounted on the substrate part 79. The other end part 31b of the light supplying/guiding member 30, the end part 41a of the characteristic light-guiding member 40, and the detecting unit 60 may be pushed by a member (not shown), secured to the substrate part 79 and optically connected to the light branching unit 71.

The substrate part 79 is made of at least one material selected from the group consisting of a semiconductor, glass, resin, ceramic, hard material (e.g., Si) and flexible material.

As shown in FIG. 1B, the detecting unit 60 is directly mounted on the substrate part 79. The characteristic changing part 50 may have a light absorbing part. If this is the case, the detecting unit 60 detects the change in the amount of light which occurs in the characteristic changing part 50, and eventually detects how much the characteristic light-guiding member 40 has been bent.

[Operation]

The light source 20 emits light. The light is applied to the light supplying/guiding member 30 and guided by the light supplying/guiding member 30 to the optical connecting unit 70. At this point, the light branching unit 71 branches the light to the characteristic light-guiding member 40. The light is applied to the characteristic light-guiding member 40, and guided by the characteristic light-guiding member 40. Thus, the light propagates from the end 73a of the light branching unit 71 to the other end 73b thereof.

At this point, the optical characteristic of the light is changed by the characteristic changing part 50. This change of the optical characteristic corresponds to the bending of the characteristic light-guiding member 40. That part of the light which has changed in optical characteristic, and the other part of the light which has not changed in optical characteristic, are guided by the characteristic light-guiding member 40 to the reflecting part 42 and reflected by the reflecting part 42. A part of the light so reflected is changed again in optical characteristic by the characteristic changing part 50. Thus, the

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characteristic changing part 50 changes optical characteristic of the light two times. That part of the light which has changed in optical characteristic, and the remaining part of the light which has not change in optical characteristic are guided by the characteristic light-guiding member 40 to the optical connecting unit 70. At this point, the light is branched by the light branching unit 71 to the detecting unit 60. That is, the light is applied to the detecting unit 60. Thus, the light returns from the other end 73b of the light branching unit 71 to the end 73a thereof.

The characteristic changing part 50 may have a light absorbing part. In this case, the amount of light changes twice, each time in accordance with the bending of the characteristic light-guiding member 40. The light thus changed in amount is detected by the detecting unit 60. Thus, the detecting unit 60 detects the amount of light changed in the characteristic changing part 50 and hence detects how much the characteristic light-guiding member 40 has been bent.

In this embodiment, the light applied from the light source 20 is reflected at the reflecting part 42 including the characteristic changing part 50 and used as a relay point, and then propagates to the detecting unit 60.

[Advantages]

In this embodiment, the light branching unit 71 thus branches light to the characteristic light-guiding member 40 and the detecting unit 60. That is, the light is reflected and then propagates in the opposite direction in this embodiment. The optical sensor 10 can therefore be made smaller than otherwise. The optical sensor 10 according to this embodiment can be incorporated in a small high-precision device (not shown).

The small high-precision device may be, for example, a thin and long member such as the insertion section of a medical endoscope, the insertion section of an industrial endoscope, a manipulator, or a catheter. In this case, this embodiment is particularly useful, because the light is reflected and then propagates in the opposition direction.

As shown in, for example, FIG. 5C, a laser light source 113 may be connected to one end part of an optical fiber 101, and a photoelectric transducer device 115 is arranged at the other end part of the optical fiber 101. In this case, light propagates in one direction only. If the optical sensor 10 is used in combination with a small high-precision device, a part of the optical sensor 10 will be inevitably arranged outside the high-precision device. The optical sensor 10 has low installation freedom.

However in this embodiment, the light is reflected and then propagates back, and only the characteristic light-guiding member 40 including the characteristic changing part 50 needs to be arranged in a small high-precision device. The freedom of positioning of the optical sensor 10 can therefore be maintained.

Further, the optical sensor 10 according to this embodiment can be made small, because both the light source 20 and the detecting unit 60 are arranged at one end part 73a of the light branching unit 71.

The optical sensor 10 according to this embodiment can be made small and simple because the light branching unit 71 functions as light guiding path 75.

Further, since the optical connecting unit 70 is optically connected, on the substrate part 79, to the light supplying/guiding member 30, characteristic light-guiding member 40 and detecting unit 60, the optical sensor 10 according to this embodiment can be manufactured with less labor than otherwise, and can be mass-produced at low cost.

Still further, the substrate part 79 increases the strength of the small optical sensor 10. Since the substrate part 79 is made

of a flexible material, the light branching unit **71** can be bent. This increases the freedom of positioning of the optical sensor **10**.

Moreover, the characteristic changing part **50**, which is arranged on the characteristic light-guiding member **40** only, changes the optical characteristic in accordance with the bending of the characteristic light-guiding member **40**. Therefore, the optical characteristic can be reliably changed in accordance with the bending of the characteristic light-guiding member **40**. In addition, the detecting unit **60** can reliably detect how much the characteristic light-guiding member **40** is bent. Further, the detecting unit **60** can detect the bending of the characteristic light-guiding member **40**, irrespective of the bending or twisting of the light supplying/guiding member **30**.

In this embodiment, the light source **20** may be mounted on the substrate part **79** and may thereby be optically connected directly to the optical connecting unit **70**, as shown in FIG. 1E.

In this embodiment, the reflecting part **42** can reliably reflect the light. This enhances the detection precision of the detecting unit **60**, and prevents the light from radiating outside from the other end part **41b** of the characteristic light-guiding member **40**. The light may be reflected by the other end part **41b** of the characteristic light-guiding member **40**. In this case, the reflecting part **42** can be dispensed with, possibly reducing the manufacturing cost of the optical sensor **10**.

The detecting unit **60** is mounted on the substrate part **79** in the present embodiment. Nonetheless, the detecting unit **60** need not be mounted on the substrate part **79**, and may be optically connected, like the light source **20**, to other end **731b** of the end part **73a** of the light branching unit **71** by a depending light guiding member (e.g., optical fiber, not shown).

Moreover, the characteristic changing part **50** may be a wavelength-changing member (e.g., phosphor) that changes the wavelength of the light. If this is the case, the amount of the light changed in wavelength by the characteristic changing part **50** differs in accordance with how much the characteristic light-guiding member **40** is bent. If the characteristic light-guiding member **40** is bent upwards, positioning the characteristic changing part **50** inside the characteristic light-guiding member **40**, the amount of light changed in wavelength by the characteristic changing part **50** will decrease more than in the case the characteristic light-guiding member **40** extends straight. If the characteristic light-guiding member **40** is bent downwards, positioning the characteristic changing part **50** outside the characteristic light-guiding member **40**, the amount of light changed in wavelength by the characteristic changing part **50** will increase more than in the case the characteristic light-guiding member **40** extends straight. Thus, the amount of light propagating to the detecting unit **60** changes by the amount of light that the characteristic changing part **50** changes the wavelength is changed.

In this embodiment, the characteristic changing part **50** changes the optical characteristic in accordance with, for example, the bending of the characteristic light-guiding member **40**. Instead, the characteristic changing part **50** may change the optical characteristic in accordance with, for example, at least one physical amount selected from the group consisting of the bending direction of the characteristic light-guiding member **40**, the bending amount of a high-precision device, the bending direction of the high-precision device and the operating amount of the high-precision device.

[Configuration]

The second embodiment will be described as to only the configuration features distinguishing this embodiment from the first embodiment, with reference to FIG. 2A and FIG. 2B.

As shown in FIG. 2B, the light supplying/guiding member **30** is monolithically formed on the substrate part **79**. The configuration need not be limited to this, nevertheless. At least of the light source **20**, the light supplying/guiding member **30** and detecting unit **60a**, **60b** and **60c** may be monolithically formed on the substrate part **79**. If the light source **20** is monolithically mounted on the substrate part **79**, it may be directly connected to the optical connecting unit **70**. If the light supplying/guiding member **30** is connected to the optical connecting unit **70**, the light source **20** and the light supplying/guiding member **30** may be monolithically mounted on the substrate part **79**.

As FIG. 2A and FIG. 2B show, characteristic changing parts **50a**, **50b** and **50c** are arranged. The characteristic changing parts **50a**, **50b** and **50c** have a light absorbing part each. The absorbing parts of the characteristic changing parts **50a**, **50b** and **50c** absorb lights of different wavelengths each other. That is, wavelength of light A that the characteristic changing parts **50a** is absorbed, wavelength of light B that the characteristic changing parts **50b** is absorbed and wavelength of light C that the characteristic changing parts **50c** is absorbed are differed each another. This is because the characteristic changing parts **50a**, **50b** and **50c** change the optical characteristics of the light A, light B and light C, respectively, to different values.

In this embodiment, the light source **20** emits light A, light B and light C independently of one another. Since only one light supplying/guiding member **30** is provided, the light A, B and C are guided as a synthesized light by the light supplying/guiding member **30**. The light source **20** emits light containing the lights A, B and C. The light supplying/guiding member **30** and the characteristic light-guiding member **40** may be formed of optical fibers that can guide light in a broad band.

As shown in FIG. 2B, the characteristic changing parts **50a** and **50b** are arranged on, for example, an upper part of the characteristic light-guiding member **40**, in the diameter direction of the characteristic light-guiding member **40**. The characteristic changing part **50b** is arranged closer to the reflecting part **42** than the characteristic changing part **50a**. Thus, a position of the characteristic changing part **50a** and a position of the characteristic changing part **50b** are different from each other in the axis of the characteristic light-guiding member **40**.

As shown in FIG. 2B, the characteristic changing part **50c** is arranged on the right in the diameter direction of the characteristic light-guiding member **40**. The characteristic changing part **50c** is spaced from the characteristic changing part **50a** by, for example, 90° in the circumferential direction of the characteristic light-guiding member **40**.

Since the characteristic changing parts **50a**, **50b** and **50c** are so arranged, detecting units **60** detect not only bending amount of characteristic light-guiding member **40**, but also bending position of the member **40**.

Since the characteristic changing parts **50a** and **50b** are so arranged as specified above, the detecting units **60** can detect that bending amount of the characteristic light-guiding member **40** at different positions in the axial direction of the characteristic light-guiding member **40**.

Since the characteristic changing parts **50a** and **50b** are so arranged as specified above, the detecting units **60** can detect the direction in which the characteristic light-guiding member **40** is bent.

As shown in FIG. 2A and FIG. 2B, detecting units **60a**, **60b** and **60c** are arranged at the detecting unit **60** in the present embodiment.

For example, the detecting unit **60a** has a band selecting unit **61a** associated with the characteristic changing part **50a** and configured to select only the light whose optical characteristic has been changed by the characteristic changing part **50a**. The characteristic changing part **50a** detects the light selected by the band selecting unit **61a**, therefore detects bending amount and bending position of the characteristic light-guiding member **40**.

The detecting unit **60b** has a band selecting unit **61b** associated with the characteristic changing part **50b** and configured to select only the light whose optical characteristic has been changed by the characteristic changing part **50b**. The characteristic changing part **50b** detects the light selected by the band selecting unit **61b**, therefore detects bending amount and bending position of the characteristic light-guiding member **40**.

The detecting unit **60c** has a band selecting unit **61c** associated with the characteristic changing part **50c** and configured to select only the light whose optical characteristic has been changed by the characteristic changing part **50c**. The characteristic changing part **50c** detects the light selected by the band selecting unit **61c**, therefore detects bending amount and bending position of the characteristic light-guiding member **40**.

Thus, the detecting units **60** are used in the same number as the characteristic changing parts **50**. More precisely, the detecting units **60a**, **60b** and **60c** have band selecting units **61a**, **61b** and **61c**, respectively, which select the lights whose optical characteristics have been changed by the characteristic changing parts **50a**, **50b** and **50c**, respectively. The detecting units **60a**, **60b** and **60c** detect the lights selected by the band selecting units **61a**, **61b** and **61c**, respectively.

The band selecting units **61a**, **61b** and **61c** are mounted on the substrate part **79**. Alternatively, they may be monolithically formed with the substrate part **79**. Each of the band selecting units **61a**, **61b** and **61c** is at least one of a dispersion-type spectrometer and an interference-type spectrometer. The dispersion-type spectrometer has at least one of a prism, a grating and both. The interference-type spectrometer has, for example a color filter that allows the passage of light falling in a desirable wavelength range. The interference-type spectrometer only needs to limit the band.

This embodiment has light branching units **71a** and **71b**.

The light branching unit **71a** branches the light guided by the light supplying/guiding member **30**, to the characteristic light-guiding member **40**, and branches the light guided by the characteristic light-guiding member **40**, to the light branching unit **71b**.

The light branching unit **71b** branches this light branched by the light branching unit **71a** to the band selecting units **61a**, **61b** and **61c**.

The light branching units **71a** and **71b** have, for example, an optical fiber functioning as light guiding path **75**.

[Operation]

The light source **20** emits, for example, two lights A, B and C independently of each other. These lights A, B and C are applied to the light supplying/guiding member **30** in synthesized state. The light supplying/guiding member **30** guides the light to the optical connecting unit **70**. The lights A, B and C are branched by the light branching unit **71a** to the charac-

teristic light-guiding member **40**. The lights A, B and C are applied to the characteristic light-guiding member **40**. The characteristic light-guiding member **40** guides the lights A, B and C to the reflecting part **42**. The reflecting part **42** reflects the lights A, B and C.

At this point, the characteristic changing parts **50a** change the optical characteristic (e.g., amount) of the light A two times, as in the first embodiment. The light branching unit **71a** branches the light A, so changed in optical characteristic, to the light branching unit **71b**. The light branching unit **71b** branches the light A to the band selecting units **61a**, **61b** and **61c**. The light A is selected by the band selecting unit **61a** and then detected by the detecting unit **60a**. The light A is branched to the band selecting units **61b** and **61c**, too, but is not selected by the band selecting units **61b** and **61c** nor detected by the detecting units **60b** and **60c**, respectively.

The characteristic changing part **50b** changes the optical characteristic of the light B twice. The light B is selected by the band selecting unit **61b** and detected by the detecting unit **60b**.

The characteristic changing part **50c** changes the optical characteristic of the light C two times. The light C is selected by the band selecting unit **61c** and detected by the detecting unit **60c**.

[Advantages]

In this embodiment, the characteristic changing parts **50a**, **50b** and **50c** are used, making it possible to detect how much and where the characteristic light-guiding member **40** is bent. Thus, one characteristic light-guiding member **40** suffices to achieve detection at some points that the number of characteristic light-guiding member **40** is not increased. Further, the characteristic changing parts **50a** and **50b** can detect how much the characteristic light-guiding member **40** is bent at different positions in the axial direction of the characteristic light-guiding member **40**. Still further, the characteristic changing parts **50a** and **50c** can detect in which direction the characteristic light-guiding member **40** is bent. Thus, various information items can be acquired in this embodiment.

In this embodiment, the characteristic changing parts **50a**, **50b** and **50c** and the band selecting units **61a**, **61b** and **61c** cooperate to detect the bending amount of the characteristic light-guiding member **40**. Also, they cooperate in detecting the position where the characteristic light-guiding member **40** is bent.

In this embodiment, in the light source **20**, the light supplying/guiding member **30** and the detecting units **60a**, **60b** and **60c**, or at least one of these components is monolithically mounted on the substrate part **79**. Further, the band selecting units **61a**, **61b** and **61c** are monolithically mounted on the substrate part **79**. Therefore, the optical sensor **10** according to this embodiment can be made small, and the connection of its components can be simple, and the optical sensor **10** can be made at low cost.

In this embodiment, the band selecting units **61a**, **61b** and **61c** can detect the lights A, B and C, independently and respectively. This helps to make the optical sensor **10** small and to manufacture the same at low cost.

The characteristic changing parts **50a**, **50b** and **50c** may be constituted by wavelength changing members.

In this case, the light source **20** emits the lights A, B and C, independently of one another, or emits light including the lights A, B and C.

In this embodiment, light sources **20a**, **20b** and **20c** may be provided, which emits lights A, B and C, respectively, as shown in FIG. 2C. Further, light supplying/guiding member **30a**, **30b**, and **30c** may be provided, which are optically connected to the light sources **20a**, **20b** and **20c**, respectively, and

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guide lights A, B and C, respectively. The light applying/guiding members 30a, 30, and 30c are fitted in the recess part 79a and are optically connected to the light branching unit 71a. The nodes of the light applying/guiding members 30a, 30, and 30c and the light branching unit 71a are covered with a cover 90.

In this embodiment, the light applying/guiding members 30a, 30, and 30c can be easily axially aligned, because they are fitted in the recess part 79a. Moreover, the cover 90 can protect the nodes of the light applying/guiding members 30a, 30, and 30c.

Third Embodiment

[Configuration]

The third embodiment will be described with reference to FIG. 3 as to only the configuration features distinguishing the embodiment from the first and second embodiments. That is, it will be described how the light source 20, light supplying/guiding member 30, characteristic light-guiding members 40a, 40b and 40c and detecting units 60a, 60b and 60c are arranged in a specific relation.

One light source 20 and one light supplying/guiding member 30 are provided. The light source 20 and the light supplying/guiding member 30 are arranged at one side 79e of the substrate part 79, not one end part 79c or the other end part 79d. The light supplying/guiding member 30 extends, for example, at right angles to the line connecting the end part 79c and the other end part 79d.

The characteristic light-guiding members 40a, 40b and 40c are arranged at the other end part 79d of the substrate part 79. The characteristic light-guiding members 40a, 40b and 40c are optically connected to the light guiding path 75 of the optical connecting unit 70. When the characteristic light-guiding members 40a, 40b and 40c are fitted in the recess part 79a, the cores (not shown) of the characteristic light-guiding members 40a, 40b and 40c is optically connected to the core 75a of the light guiding path 75. The characteristic light-guiding members 40a, 40b and 40c are arranged, for example, along a line connecting the end part 79c and other end part 79d of the substrate part 79. The characteristic light-guiding members 40a, 40b and 40c are arranged parallel to one another.

The detecting units 60a, 60b and 60c are arranged at the other end part 79d side of the substrate part 79. The detecting units 60a, 60b and 60c are optically connected to the light guiding path 75 of the optical connecting unit 70, by a detecting light applying/guiding member 63 that is an optical fiber. When the detecting light applying/guiding member 63 are fitted in the recess part 79a, the cores (not shown) of the detecting light applying/guiding member 63 is optically connected to the core 75a of the light guiding path 75. The detecting light applying/guiding member 63 is arranged, extending along, for example, a line connecting the end part 79c and other end part 79d of the substrate part 79.

Thus, the light source 20, light supplying/guiding member 30, characteristic light-guiding members 40a, 40b and 40c and detecting units 60a, 60b and 60c and detecting light applying/guiding member 63 are arranged in a T-shaped pattern.

It will be explained how the characteristic light-guiding members 40a, 40b and 40c, the detecting units 60a, 60b and 60c and the optical connecting unit 70 are configured.

The characteristic light-guiding member 40a has a characteristic changing part 50a, the characteristic light-guiding member 40b has a characteristic changing part 50b, and the characteristic light-guiding member 40c has a characteristic

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changing part 50c. The characteristic light-guiding members (40a to 40c), characteristic changing parts (50a to 50c) and light branching units (71a to 71c) are provided in the same number, for example 3. In this case, the light source 20 emits light including the lights A, B and C.

The optical connecting unit 70 further has the light guiding path 75, which is, for example, an optical fiber. The light guiding path 75 is optically connected to the characteristic light-guiding members 40a, 40b and 40c and the detecting light applying/guiding member 63. Thus, the light guiding path 75 is arranged along a straight line connecting the end part 79c and the other end part 79d, and also along a straight line at right angles to that straight line. The light guiding path 75 guided to the characteristic light-guiding members 40a, 40b and 40c light guided by the light supplying/guiding member 30 and guided to the detecting light applying/guiding member 63 light guided by the characteristic light-guiding members 40a, 40b and 40c.

The light branching units 71a, 71b and 71c are each a combination of a reflecting/transmitting part for reflecting and transmitting light or reflecting part for reflecting light, and a transmitting part for transmitting light. The light branching units 71a, 71b and 71c are arranged on the light guiding path 75. The light branching units 71a, 71b and 71c extend along a straight line at right angles to the straight line connecting the end part 79c and the other end part 79d. The light branching units 71a, 71b and 71c have a groove each. The groove inclines at a desirable angle to the straight line extending from the end part 79c to the other end part 79d.

As described above, the light branching units 71a, 71b and 71c are provided in the same number as the characteristic light-guiding members 40a, 40b and 40c. The light branching units 71a, 71b and 71c need to branch the light emitted from the light source 20 and guided by the light supplying/guiding member 30 to the three characteristic light-guiding members 40a, 40b and 40c. This is why the light branching units 71a, 71b and 71c control the light-branching ratio so that the light may propagate to the characteristic light-guiding members 40a, 40b and 40c. The control is performed in accordance with at least one selected from the group consisting of the configuration of the reflecting/transmitting parts (not shown) of the light branching units 71a, 71b and 71c, the angle of the above-mentioned grooves (not shown) and the refractive index of the material filling the grooves. Each of the light branching units 71a, 71b and 71c is configured to reflect the light and transmit the light. As described above, the light source 20, light supplying/guiding member 30, characteristic light-guiding members 40a, 40b and 40c and detecting units 60a, 60b and 60c and detecting light applying/guiding member 63 are arranged in a T-shaped pattern. Therefore, when the light branching units 71a, 71b and 71c reflect the light, the light branching units 71a, 71b and 71c branched the light so that the light branching units 71a, 71b and 71c reflect the light at 90° to the direction in which the light is applied to them, thus making the light propagate to the characteristic light-guiding members 40a, 40b and 40c. When the light branching units 71a, 71b and 71c is transmitted the light, the light branching units 71a, 71b and 71c branches the light, so that the light is applied to the branching units 71a, 71b and 71c not inclined thereto, and passes through the light branching units 71a, 71b and 71c.

The light guiding path 75 includes the light branching units 71a, 71b and 71c is sandwiched a substrate part 81a and 81b. The substrate parts 81a and 81b are made of, for example, at least one material selected from the group consisting of Si,

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SiOx, Parlylen, silicon resin and polyimide. The refractive index of the substrate part **81a** is higher than that of the substrate part **81b**.

The substrate part **79** is made of at least one of a semiconductor, glass, resin, ceramic, hard material, for example Si and flexible material.

The light source **20**, characteristic light-guiding member **40**, detecting unit **60** and light branching unit **71** may be used in various numbers. The light source **20** may be used in number L, the characteristic light-guiding member **40** may be used in number M, and the detecting unit **60** may be used in number N. That is, $L \geq 1$, $M \geq 1$ and $N \geq 1$. In this case, at least one of $L \neq M$ and $L \neq N$ is hold. Further, M and N may be the same number or different numbers. The light branching unit **71** is used in a desirable number that accords with the number of characteristic light-guiding members **40** used and the number of detecting units **60** used.

[Operation]

The light source **20** emits light containing, for example, lights A, B and C. These lights are applied to the light supplying/guiding member **30**. The light supplying/guiding member **30** guides the lights to the light guiding path **75**.

The light is guided from the light guiding path **75** to the branching units **71a**. The branching unit **71a** reflects the light by 90°, branching the light to the characteristic light-guiding members **40a**. The light branched is guided by the light guiding path **75** to the characteristic light-guiding members **40a**. The light is then reflected by the reflecting part **42**. At this point, the light A contained in the light is changed twice in optical characteristic (e.g., amount) by the characteristic changing part **50a**, as in the first embodiment. The light containing the light A, now changed in optical characteristic, is applied from the characteristic light-guiding members **40a** through the light guiding path **75** to the branching unit **71a**, passes through the branching unit **71a**, and is applied to the detecting light applying/guiding member **63** through the light guiding path **75**. The detecting light applying/guiding member **63** guides the light containing the light A. The light is detected by the detecting unit **60a**.

The light passes through the branching unit **71a**, is reflected by the branching unit **71b** by 90°, is thereby branched to the characteristic light-guiding member **40b** through the light guiding path **75** and is guided by the characteristic light-guiding member **40b**. The light is then reflected by the reflecting part **42**. At this point, the light B contained in the light is changed twice in optical characteristic (e.g., amount) by the characteristic changing part **50b**, as in the first embodiment. The light containing the light B so changed in optical characteristic is applied through the light guiding path **75** to the branching unit **71b**, passes through the branching unit **71b**, and is applied through the light guiding path **75** to the detecting light applying/guiding member **63**. The detecting light applying/guiding member **63** guides the light containing the light B. The light is detected by the detecting unit **60b**.

The light passes through the branching units **71a** and **71b**, is reflected by 90° by the light branching unit **71c** and thereby branched the characteristic light-guiding member **40c** through the light guiding path **75**, and is guided by the characteristic light-guiding member **40c**. Then, the light is reflected by the reflecting part **42**. At this point, the light is changed twice in optical characteristic (e.g., amount) by the characteristic changing part **50c**, as in the first embodiment. The light containing the light C so changed in optical characteristic is applied from the characteristic light-guiding member **40c** through the light guiding path **75** to the branching unit **71c**, passes through the branching unit **71c**, and is

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applied through the light guiding path **75** to the detecting light applying/guiding member **63**. The detecting light applying/guiding member **63** guides the light containing the light C. The light is detected by the detecting unit **60c**.

[Advantages]

In this embodiment, the characteristic light-guiding members **40a**, **40b** and **40c** have characteristic changing parts **50a**, **50b** and **50c**, respectively. The characteristic light-guiding members **40a**, **40b** and **40c** can therefore provide some detecting points, which can enhance the detection accuracy. For example, the characteristic changing parts **50a**, **50b** and **50c** are arranged at different positions in the axial directions of the characteristic light-guiding members **40a**, **40b** and **40c**. This makes it possible to detect how much the characteristic light-guiding members **40a**, **40b** and **40c** are bent at various positions.

In this embodiment, the branching units **71a**, **71b** and **71c** can increase the freedom in light-branching configuration. Further, the branching units **71a**, **71b** and **71c** can branch the light at high efficiency, which enhances the detection accuracy of the detecting units **60a**, **60b** and **60c**.

In this embodiment, the branching units **71a**, **71b** and **71c** can reflect light and allow the passage of light. The light containing lights A, B and C can therefore be reliably emitted. As a result, the light is branched to the characteristic light-guiding members **40a**, **40b** and **40c**, it suffices to use only one light source **20**, and the optical sensor **10** can therefore be made small and can be manufactured at low cost. Moreover, the branching ratio between the branching units **71a**, **71b** and **71c** is used, predicting the ratio of light quantities the detecting units **60a**, **60b** and **60c** will detect. This helps to control the optical sensor **10** easily.

Further, in this embodiment, the number of light sources **20** used can be smaller than the number of characteristic light-guiding members **40a**, **40b** and **40c**, because the branching units **71a**, **71b** and **71c** are used.

In this embodiment, the light source **20**, light supplying/guiding member **30**, characteristic light-guiding members **40a**, **40b** and **40c** and detecting units **60a**, **60b** and **60c** and detecting light applying/guiding member **63** can be arranged in a T-shaped pattern because the branching units **71a**, **71b** and **71c** are used. This increase the freedom of positioning the optical sensor **10**.

In this embodiment, the characteristic changing parts **50a**, **50b** and **50c** need not be provided in the same number as the characteristic light-guiding members **40a**, **40b** and **40c**. Rather, the characteristic light-guiding member **40a** may have a plurality of characteristic changing parts **50**. If this is the case, the detecting unit **60a**, for example, have a plurality of band selecting units **61** corresponds to the characteristic changing parts **50**. Alternatively, the detecting unit **60a** may be arranged corresponds to the band selecting units **61**, in one-to-one relation. This holds true of the characteristic light-guiding members **40b** and **40c** and the detecting units **60b** and **60c**. Thus, more information items can be detected than otherwise.

Fourth Embodiment

[Configuration]

The fourth embodiment will be described with reference to FIGS. 4A, 4B and 4C.

As FIGS. 4A, 4B and 4C show, a light source **20** and a light supplying/guiding member **30** are arranged at the other end part **79d** side of a substrate part **79**.

As shown in FIG. 4C, an optical connecting unit **70** has, the substrate part **79** that is rectangular plate, a low-flexibility

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sheet **83a**, a substrate part **85**, a low-flexibility sheet **83b**, and a hard-material plate **87**. The low-flexibility sheet **83a** is mounted on the substrate part **79**. The substrate part **85** is mounted on the low-flexibility sheet **83a**. On the substrate part **85**, branching units **71a**, **71b** and **71c** and light guiding paths **75** are arranged. The low-flexibility sheet **83b** is mounted on the substrate part **85**. The hard-material plate **87** is mounted on the low-flexibility sheet **83a**.

The optical connecting unit **79** has recesses part **79a**. The recesses part **79a** hold the light supplying/guiding member **30**, characteristic light-guiding members **40a**, **40b** and **40c** and light applying/guiding members **63**, securing them to the substrate part **79** and optically connecting them to the light guiding paths **75**. When the light supplying/guiding member **30**, characteristic light-guiding members **40a**, **40b** and **40c** and light applying/guiding members **63** are fitted in the recesses part **79a**, the light supplying/guiding member **30**, characteristic light-guiding members **40a**, **40b** and **40c** and light applying/guiding members **63** are fitted are optically connected to the light guiding paths **75**. More specifically, the cores of the light supplying/guiding member **30**, characteristic light-guiding members **40a**, **40b** and **40c** and light applying/guiding members **63** are optically connected to the light guiding paths **75**. The recesses part **79a** is, for example, V grooves or U grooves.

The light applying/guiding members **63** are secured to one end part **79c** of the substrate part **79**. The light supplying/guiding member **30** and the characteristic light-guiding members **40a**, **40b** and **40c** are secured to the other end part **79d** side of the substrate part **79**. The light supplying/guiding member **30** and the characteristic light-guiding members **40a**, **40b** and **40c** are arranged, for example, parallel to one another. The characteristic light-guiding members **40a**, **40b** and **40c** are arranged parallel to one another. The light supplying/guiding member **30**, the characteristic light-guiding members **40a**, **40b** and **40c** and the light applying/guiding members **63** are arranged in the same direction.

The branching units **71a**, **71b** and **71c** are arranged in the light guiding paths **75**, respectively. The branching units **71a**, **71b** and **71c** are provided in the same number as the characteristic light-guiding members **40a**, **40b** and **40c**. Each of the branching units **71a**, **71b** and **71c** is composed of a transmitting part and a reflecting part. The branching units **71a**, **71b** and **71c** reflect (branch) the lights guided by the light guiding paths **75** to the characteristic light-guiding members **40a**, **40b** and **40c**. The characteristic light-guiding members **40a**, **40b** and **40c** transmit (branch) the lights to the light guide member. The branching units **71a**, **71b** and **71c** control the reflection-to-transmission ratio in accordance with their transmitting characteristic and reflecting characteristic and with the angles defined by the lights applied from the light supplying/guiding member **30** to the branching units **71a**, **71b** and **71c** and the lights applied from the characteristic light-guiding members **40a**, **40b** and **40c** to the branching units **71a**, **71b** and **71c**. The branching units **71a**, **71b** and **71c** are arranged such that each is inclined to the straight line connecting the ends part **79a** and part **79d** of the substrate part **79**.

The angle defined by the light guiding paths **75** connecting the supplying/guiding member **30** to the branching units **71a**, **71b** and **71c** and the light guiding paths **75** holding the branching units **71a**, **71b** and **71c** and connecting the characteristic light-guiding members **40a**, **40b** and **40c** to the light applying/guiding members **63** is smaller than 90° because of the branching units **71a**, **71b** and **71c**. When the branching units **71a**, **71b** and **71c** reflect the light, the branching units **71a**, **71b** and **71c** reflect by an angle smaller than 90°, with

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respect to the direction in which they receive the light, because of light-reflecting characteristic of the branching units **71a**, **71b** and **71c**.

The low-flexibility sheet **83a** and **83b** have a smaller refractive index than the branching units **71a**, **71b** and **71c**. The low-flexibility sheets **83a** and **83b** sandwich the branching units **71a**, **71b** and **71c**, preventing light from leaking from the branching units **71a**, **71b** and **71c**.

The hard-material plate **87** protects the branching units **71a**, **71b** and **71c**, the optical/mechanical connection of the branching units **71a**, **71b** and **71c** and light supplying/guiding member **30**, the optical/mechanical connection of the characteristic light-guiding members **40a**, **40b** and **40c** and branching units **71a**, **71b** and **71c**, and the optical/mechanical connection of the light-guiding members and branching units **71a**, **71b** and **71c**. Further, the hard-material plate **87** strengthens the connection of the light supplying/guiding member **30**, characteristic light-guiding members **40a**, **40b** and **40c**, light applying/guiding members **63** and branching units **71a**, **71b** and **71c**. The hard-material plate **87** is, for example, a transparent member of glass or the like.

[Operation]

This embodiment operates almost in the same way as the third embodiment. Therefore, how it operates will not be explained.

[Advantages]

In this embodiment, owing to the branching units **71a**, **71b** and **71c** and the light guiding paths **75**, the light source **20**, light supplying/guiding member **30** and characteristic light-guiding members **40a**, **40b** and **40c** can be arranged at the other end part **79d** of the substrate part **79**, and the light applying/guiding members **63** and detecting units **60a**, **60b** and **60c** can be arranged at the end part **79c** of the substrate part **79**. In this embodiment, the branching units **71a**, **71b** and **71c** can be arranged along lines inclined to the straight line connecting the end parts **79a** and **79b** of the substrate part **79** because of their transmitting characteristic and reflecting characteristic and their inclining angle. The distance between the end parts **79a** and **79b** can therefore be shorter than in the third embodiment, and the optical sensor **10** can be made smaller.

In this embodiment, the hard-material plate **87** can protect the optical and mechanical connection in the optical connecting unit **70**, increasing the connection strength.

The light source **20** and the light supplying/guiding member **30** may be arranged at the end part **79c** side of the substrate part **79**. The light source **20** and detecting units **60a**, **60b** and **60c** may be connected directly to the optical connecting unit **70**.

The present invention is not limited to the embodiments described above. The components of any embodiment can be modified in various manners in reducing the invention to practice. Further, the components of any embodiment described above may be combined, if necessary, in various ways to make different inventions.

What is claimed is:

1. An optical sensor comprising:
 - a light source configured to emit light;
 - a characteristic light-guiding member configured to guide the light emitted from the light source;
 - a characteristic changing part arranged in the characteristic light-guiding member and configured to change an optical characteristic of the light in accordance with how much the characteristic light-guiding member is bent;

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a detecting unit configured to detect the light changed in optical characteristic by the characteristic changing part and guided by the characteristic light-guiding member; and

an optical connecting unit configured to connect optically the light source, the characteristic light-guiding member and the detecting unit,

wherein the optical connecting unit has a light branching unit configured to branch the light emitted from the light source to the characteristic light-guiding member, and to branch the light guided by the characteristic light-guiding member to the detecting unit.

2. The optical sensor according to claim 1, wherein a plurality of the characteristic changing parts are provided, each being configured to change the optical characteristic of the light by to a different value; the detecting unit is provided in the same number as the characteristic changing parts, each having a band selecting unit associated with one characteristic changing part and configured to select only the light whose optical characteristic has been changed by the associated characteristic changing part; and the detecting unit configured to detect the light selected by the band selecting unit in the detecting unit.

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3. The optical sensor according to claim 2, wherein the light source is provided in number L, the characteristic changing part is provided in number M and the detecting units are provided in number N, where $L \geq 1$, $M \geq 1$ and $N \geq 1$, and at least one of $L \neq M$ and $L \neq N$ is hold.

4. The optical sensor according to claim 3, wherein each of the light sources further has a substrate part including the light branching unit, and at least one of the light source and detecting unit are monolithically mounted on the substrate part.

5. The optical sensor according to claim 4, wherein the band selecting unit is monolithically mounted on the substrate part.

6. The optical sensor according to claim 5, wherein the band selecting unit is composed of at least one of a dispersion-type spectrometer and an interference-type spectrometer.

7. The optical sensor according to claim 6, wherein the light branching unit reflects and transmits the light.

8. The optical sensor according to claim 7 wherein the substrate part of the substrate part is made of a flexible material.

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